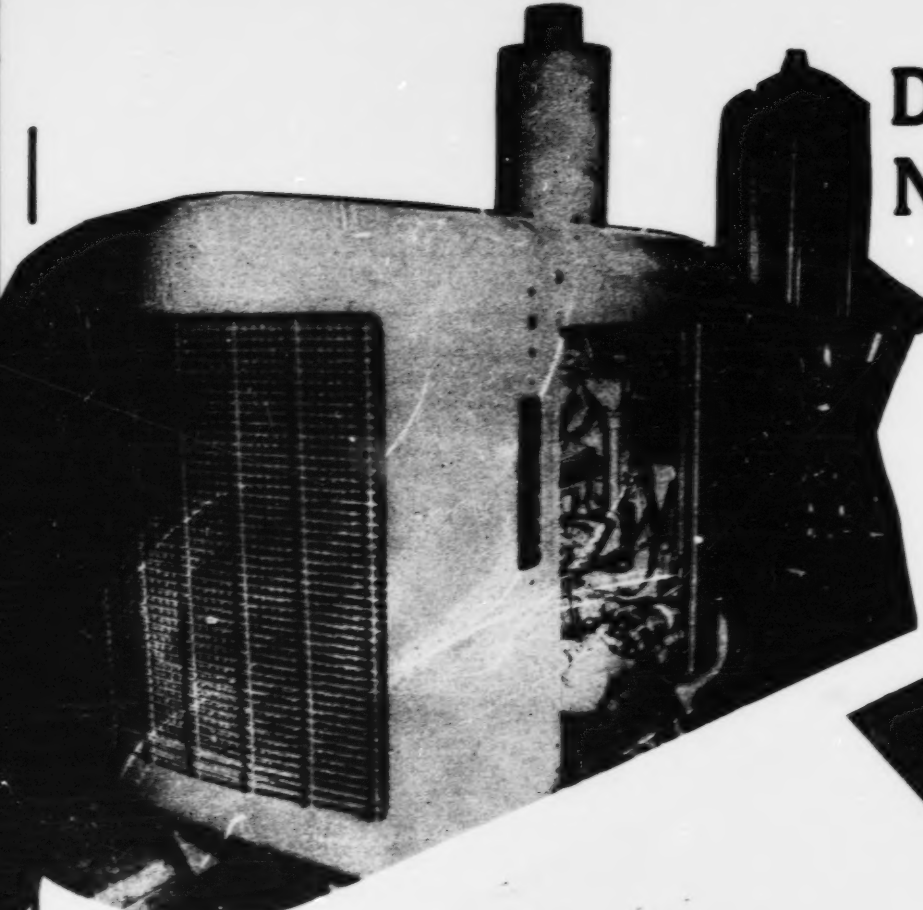
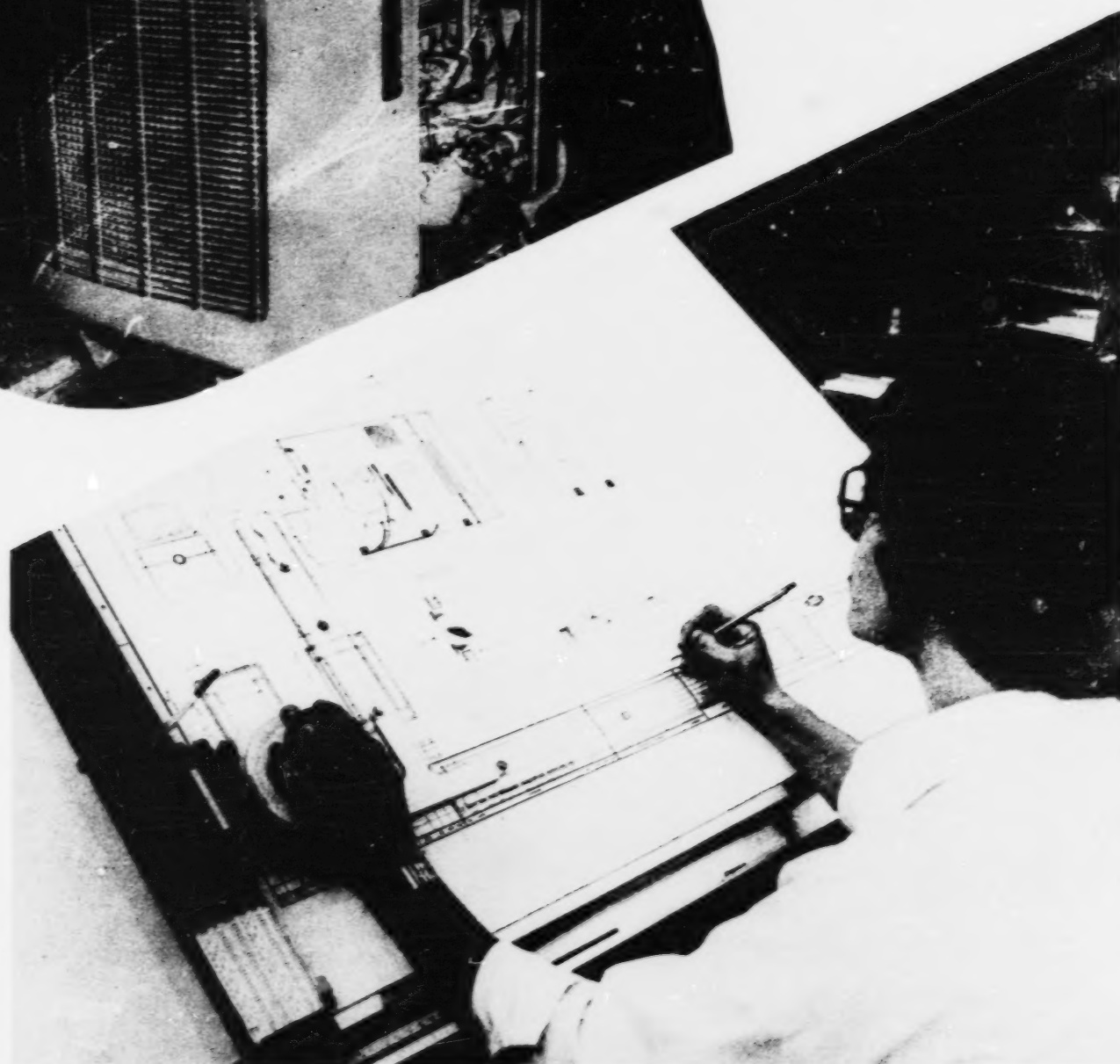




Diamond Drill Noise Study

Phase 2



Heathwood Engineering Associates Limited - Kirkland Lake, Ontario
Noranda Research Centre - Pointe-Claire, Quebec



CONTRACT REPORT NO. 05Q80-00096

DIAMOND DRILL NOISE STUDY

PREPARED FOR THE

DEPARTMENT OF ENERGY MINES & RESOURCES

CANMET

MINING RESEARCH LABORATORIES

PHASE II

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A number of people contributed to the success of this part of the project. Morissette Diamond Drilling provided assistance with the Hatz diesel engine. Mario Gauthier and his staff at the Northern College drilling school provided both the equipment for and assistance with the measurements. Dr Tony F Embleton of the National Research Council provided much appreciated advice and the Canadian Diamond Drilling Association, through its subcommittee under the chairmanship of Henry Skrowronski, gave guidance to the program.



ABSTRACT

This report covers the second phase of a multi part program aimed at reducing the noise level on diamond drills. The work covered includes a definition of the noise level components for surface equipment, a review of some conventional techniques and the design of an engine enclosure.

In general, the noise emanates equally from four sources; namely, the engine, the water pump, the transmission and the drill head.

An engine enclosure has been designed to reduce the engine noise to an acceptable level. Work remains to find solutions for noise issuing from the other three sources. Once this has been done, the complete program must then be repeated for underground drills.

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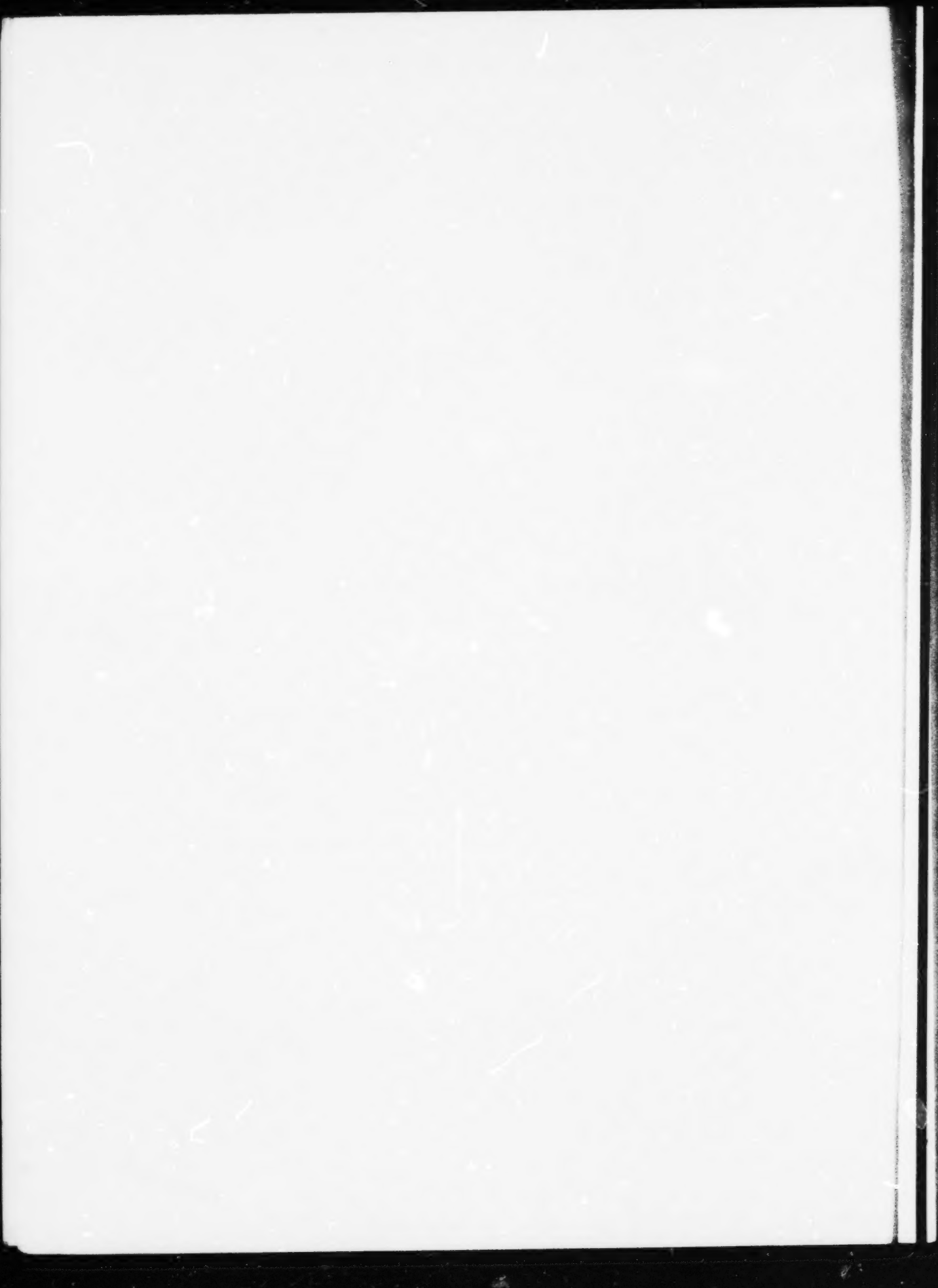
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SECTION 1

INTRODUCTION



DIAMOND DRILL NOISE STUDY

PHASE II

1.0 INTRODUCTION

Recent regulations under the Occupational Health and Safety Act have placed greater emphasis on noise control on all equipment. It is evident that these restrictions will be made even more stringent. Table 1.1, taken from the Ontario Gazette, gives a good indication of the levels that will be expected throughout Canada in the near future.

When these restrictions are applied to new equipment where new models and designs are generated frequently, there is ample opportunity to meet these standards. However, in an industry such as the Diamond Drilling Industry, where new equipment does not reflect new designs and where much of the equipment in use is generally rebuilt and has been used for a number of years, it is far more difficult to meet the noise suppression requirements. Nevertheless, noise levels on diamond drills are known to be exceedingly high with a number of people in the industry suffering from loss of hearing.

To assist the drilling industry in reducing the noise on their equipment, a project, funded by CANMET, was initiated in 1979. Because of the complexity of the overall problem and the need to gear solutions to the drilling industry, the project was phased, with the first phase designed to present an over-view of the problem at hand.

TABLE 1.1

NEW NOISE LEVEL REGULATIONS *

<u>COLUMN 1</u>	<u>COLUMN 2</u>
<u>SOUND LEVEL</u> <u>dB(A)</u>	<u>MAXIMUM PERIODS</u> <u>IN HRS PER DAY</u>
80	16
85	8
90	4
95	2
100	1
105	1/2
110	1/4
115	1/8
greater than 115	0

<u>COLUMN 1</u>	<u>COLUMN 2</u>
<u>PEAK SOUND PRESSURE</u> <u>LEVEL dB(A)</u>	<u>MAXIMUM NUMBER OF</u> <u>IMPULSES PER DAY</u>
120	10,000
130	1,000
140	100
greater than 140	0

* Proposed for the Province of Ontario

The first report (Phase I) was presented to the industry in the Spring of 1980 and consisted of a general survey of the types of equipment currently in use in the industry. From this survey, it is evident that approximately 70% of all the equipment is used on the surface and is diesel powered. The remaining 30% is used underground and is pneumatically powered. There is a small number of other drills either electrically powered or gas powered but that number is very insignificant. The noise level for surface mounted, diesel equipment is about 106 dBA. The noise level for pneumatic underground equipment is about 120 dBA. When these figures are compared with the figures in Table 1.1, it can be seen that there is a big difference. At the end of Phase I, the overall extent of the problem was fairly well defined although the exact origin of the noise had not yet been determined. As well, solutions had only been discussed in a general way. A number of specialized products such as mufflers and sound isolation materials had turned up but had not been evaluated.

In the Summer of 1980 the second phase of the project was initiated and is the subject of this report. Its objectives are detailed in the next section but briefly involve a more detailed evaluation of sound sources, the design of an engine enclosure and an examination of some of the available accessories which could be used to reduce noise levels.

The work of both projects was contracted to Heathwood Engineering Associates Limited of Kirkland Lake. Heathwood was assisted coequally by Noranda Research Centre in Pointe Claire, Quebec. Through the Canadian Diamond Drilling Association, a technical committee consisting of diamond drill manufacturers and drilling contractors was established to act as a steering committee for the project. Assistance for the project was also obtained through the National Research Council of Ottawa.



SECTION 2
PHASE II OBJECTIVES



2.0 PHASE II OBJECTIVES

The statement of work (Appendix I) as outlined in the contract provided for a number of objectives.

The Phase I work had established that the overall noise levels were high. It had also established that there was likely more than one source of noise so that no simple solution existed to the overall noise abatement on the diamond drill. The first objective of Phase II was therefore to determine the numbers and levels of noise sources. Two sets of measurements were taken. One set was completed by the Noranda Research Group and was done by classical methods. The second set was done by the National Research Council using a newer, two microphone method. This latter method will be reported elsewhere.

The second part of the work was to examine the best steps in reducing the general noise level as determined in the first step. The main thrust of this work was in the preparation of plans for an engine enclosure capable of sufficiently reducing the engine noise.

As a parallel function, a number of devices in current development were also examined. These devices were a silent power system developed by Hatz, a special muffler developed by Inco and currently produced by State Industries in Winnipeg, Manitoba, a new drill muffler design undertaken by Canadian Longyear and other similar devices.

Actual measurements of the Hatz diesel system and of the State muffler were undertaken.

Finally, recommendations for future work have been included in the final sections of this report for the further consideration of CANMET and the Canadian Diamond Drilling Industry.



Figure 2.1 The Hatz silent pack mounted on the Boyles Brothers drill.

SECTION 3
OBSERVATIONS

3.0 OBSERVATIONS

As outlined in the section on Measurements, four separate noise sources were delineated, more from the standpoint of logical grouping of components rather than actual noise source evaluation. The basis for grouping was in terms of treatable elements. The four noise sources were the engine, the transmission, including all transmission components up to the bevel gear driving the head, the bevel gear and head assembly and the water pump assembly. As can be seen from Table 6.1, the levels of each of these components vary by only 3 dBA. The total sound level is 103 dBA.

Work on noise reduction was started with the complete design of an engine enclosure and some preliminary investigations into drive design. The engine enclosure is presently ready for fabrication. It is currently felt that the best solution to reducing the transmission and head noise is by means of more effective drive design. This has been discussed with gear manufacturers and experts in the gear industry. The concensus at the moment is, that while it is possible to reduce drive noise by better drive design, no one is sure of the trade-off levels. It may be possible that the existing transmissions can be used with a simple replacement of more precise gearing and shafting. On the other hand, it may also be possible that the entire transmission would have to be scrapped in order to achieve sufficient noise reduction.

Exploratory work was done on the use of the Hatz quiet diesel engine and the State and Cowl mufflers (see Appendix II) as a means of silencing pneumatically powered underground drills. On the test drill, the Hatz produced a sound level of 90 dBA, down 8 dBA from the more conventional Deutz engine. As indicated in Section 6, both the State and Cowl mufflers reduced exhaust noise emanating from the water pump which was a vane type motor. However, they brought about no apparent benefit when used with the piston motor driving the drill. It would appear that the noise from the bevel gear and other drive components in the drill is the over-riding factor.



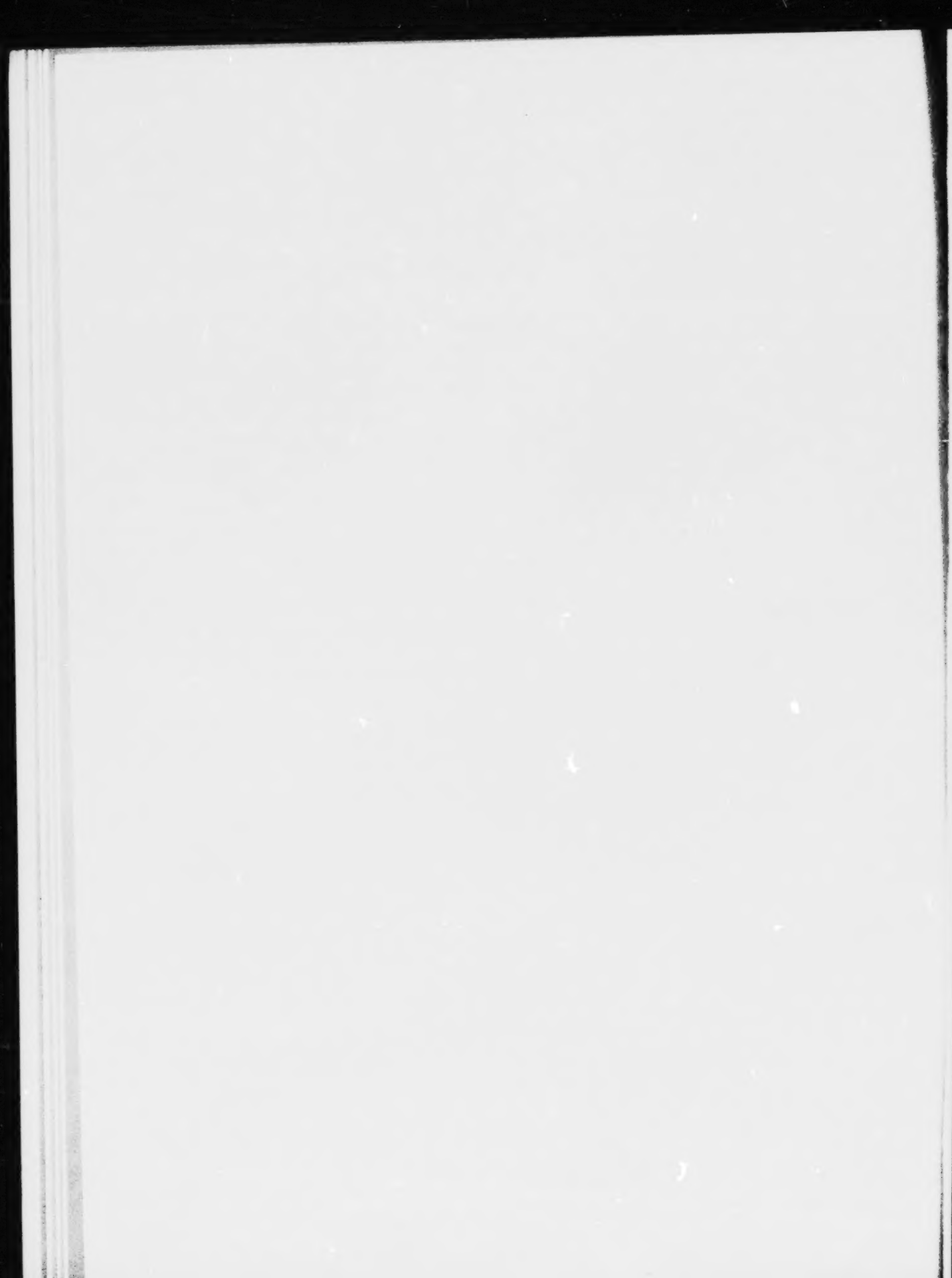
SECTION 4

CONCLUSIONS

4.0 CONCLUSIONS

- 4.1 In order to meet the 85 dBA level*, all four noise sources must be reduced to 80 dBA each.
- 4.2 The engine enclosure should be constructed and tested as soon as possible. While the enclosure is not difficult to construct, there are a number of areas where close attention to detail will be required. For this reason, it is suggested that the enclosure be constructed by an expert in the field, or by a competent contractor and that it be done under the close supervision of an engineer.
- 4.3 The Hatz engine does not reduce the sound level to the 80 dBA limit required. The noise level is in fact 90 dBA. It would not appear to be practical to place the engine within a second enclosure.
- 4.4 While tests to date on the underground pneumatic drill were not conclusive, it would appear that special attention should be given to the bevel gear and drive components and possibly to the gears operating the screw feed.

* This is dependent on the regulations. If the regulations were changed to 90 dBA then the design level would be 85 dBA.



SECTION 5

RECOMMENDATIONS AND FUTURE WORK



5.0 RECOMMENDATIONS AND FUTURE WORK

Future work will depend on the funding available. The following recommendations are given, therefore, in order of highest priority.

5.1 Throughout the program continue to provide assistance in connection with all communications between the Canadian Diamond Drilling Association and authorities having jurisdiction over noise control and continue to examine new methods as they become available.

5.2 Construct an engine enclosure as outlined in the engineering drawings supplied separately as part of this work. When the enclosure has been constructed, mount the enclosure on a drill and have sound level measurements taken to assess its suitability.

5.3 Re-examine the previous priority stating that a screw feed head should be the first to undergo noise reducing modifications. This head will be the most expensive head to work with because of the extra components.

5.4 In conjunction with specialists and drive component manufacturers, evaluate methods of reducing the noise level of all power transmission components in terms of cost and effectiveness. Be prepared to undertake some experimental work in connection with this evaluation.

5.5 Assist any member of the Canadian Diamond Drilling Association willing to make noise reducing modifications to their drilling equipment with technical backup, measurement and evaluation.

5.6 Make detailed measurements on the underground drills to identify major noise sources and levels.

5.7 In conjunction with a specialist, examine the pneumatic motor freezing problem to determine possible solutions.

5.8 Transfer all similar solutions used to reduce surface drive component noise to underground drive components.

5.9 Develop a standard method of noise level measurement to be formally adopted by the Canadian Diamond Drilling Association.

SECTION 6
MEASUREMENTS



6.0 MEASUREMENTS

The main thrust of measurement activities focused on a "typical" diesel-powered surface drilling rig as planned at the outset of the program. The objective was to identify and quantify all major noise components on the rig. While preparing to carry out these measurements, an opportunity arose to conduct some noise measurements on a drill equipped with a Hatz "silent power" diesel. This opportunity was seized even though the measurements carried out were not as extensive as would have been preferred.

It was also possible to subsequently carry out some preliminary measurements on a pneumatically-powered drill being operated underground. Both this drill and the diesel-powered unit were owned and operated by the Diamond Drilling School at the Northern College of Applied Arts and Technology in Haileybury, Ontario, without whose cooperation the measurement portion of the program would not have been possible. Except for the Hatz diesel, all measurements were carried out under normal drilling conditions.

The surface rig studied was a Boyles Model BBS-15 with mechanical screw feed, normally powered by a two-cylinder (26 KW) air-cooled Deutz diesel. A three-cylinder (29.8 KW) Hatz Model 3L30C "silent power" diesel was temporarily adapted to the drill by Morissette Diamond Drilling Limited for trial purposes. The drill was housed in a typical plywood shack (12' x 16' x 8') as shown in Figure 6.1.

6.1 Deutz Diesel Measurements

In order to be able to measure the effect of suspected noise components alone, each was operated separately whenever possible, and under the most severe operating conditions (e.g. engine operating at wide open throttle with the transmission in



Figure 6.1 The test site was typically located near Cobalt, Ontario. The test drill was a BBS-15 mounted inside a 12' x 16' x 8' high plywood shack.

neutral to measure engine noise emissions). For components like the bevel gears which could not be operated alone, an acoustical barrier was erected between the component of interest and other noise sources to reduce the noise level of the disturbing components to at least 10 dB below that of the component of interest. In this way, mixing effects were minimized.

Noise measurements were repeated in several predetermined locations around the drill and outside the drill shack under each set of conditions (e g engine alone, engine plus transmission, etc), but unless otherwise indicated, only those values from the operator's normal working position near the head are reported, since this is the data most pertinent to a drill operator's typical noise exposure.

Measurements were carried out using a GenRad Model 1933 precision sound level meter equipped with a 1/2 inch electric condenser microphone mounted on a 60 foot extension cable. Select signals were output to a Nicolet Model 446A real-time spectrum analyzer (equipped with a digital plotter) when a narrow band frequency analysis was desired (i e 400 line resolution). The instrumentation setup is shown in Figure 6.2.

The results of several narrow band analyses were superimposed on one graph and are shown in Figure 6.3. The vertical scale is A-weighted sound pressure level (i e approximately the same as would be heard by the human ear), and the horizontal scale is frequency. The 0 to 10 kHz frequency range shown is approximately the same range normally attributed to the hearing capability of adults. Inspection of Figure 6.3 indicates that most of the noise components observed have the bulk of their sound energy in the 500 to 3000 Hz range. This corresponds to the speech frequency range (the most prevalent frequencies of speech) and

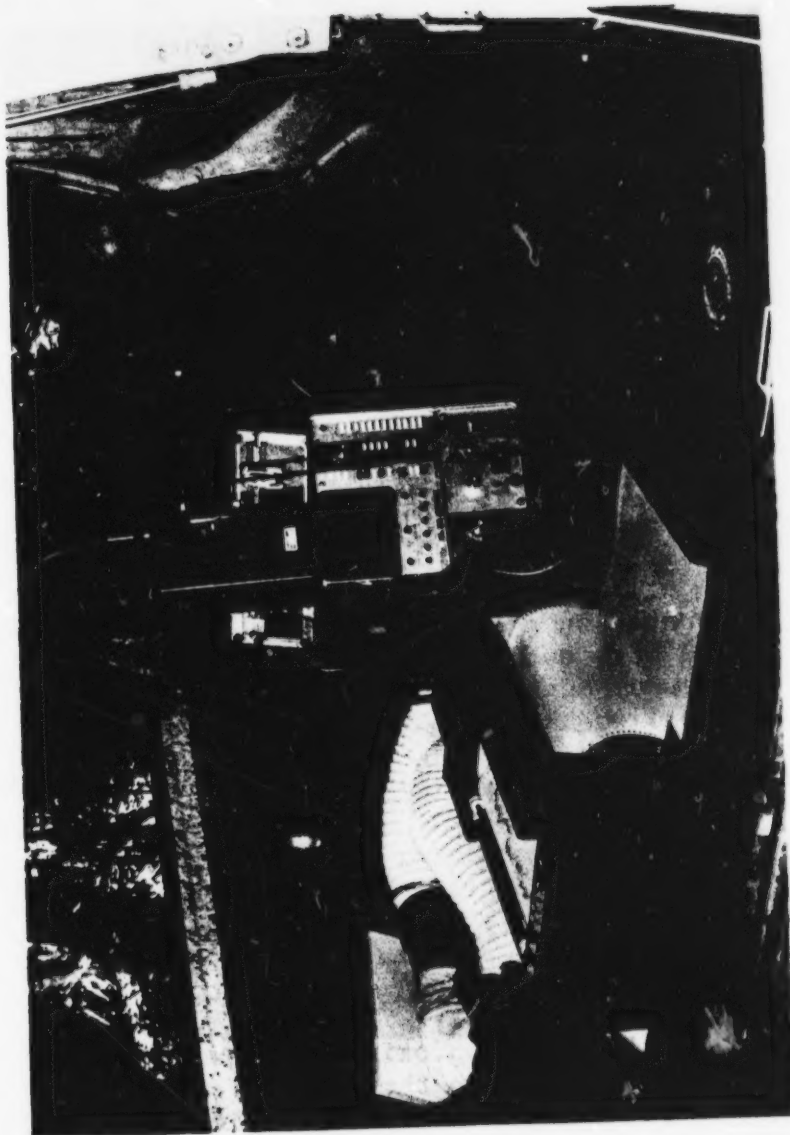


Figure 6.2 The measurement instrumentation setup for the Deutz diesel engine
(GenRad type 1933 precision sound level meter with a
Nicolet type 446A real time spectrum analyzer and digital plotter)

NOISE SPECTRA OF DIAMOND DRILL EQUIPPED WITH
DEUTZ DIESEL

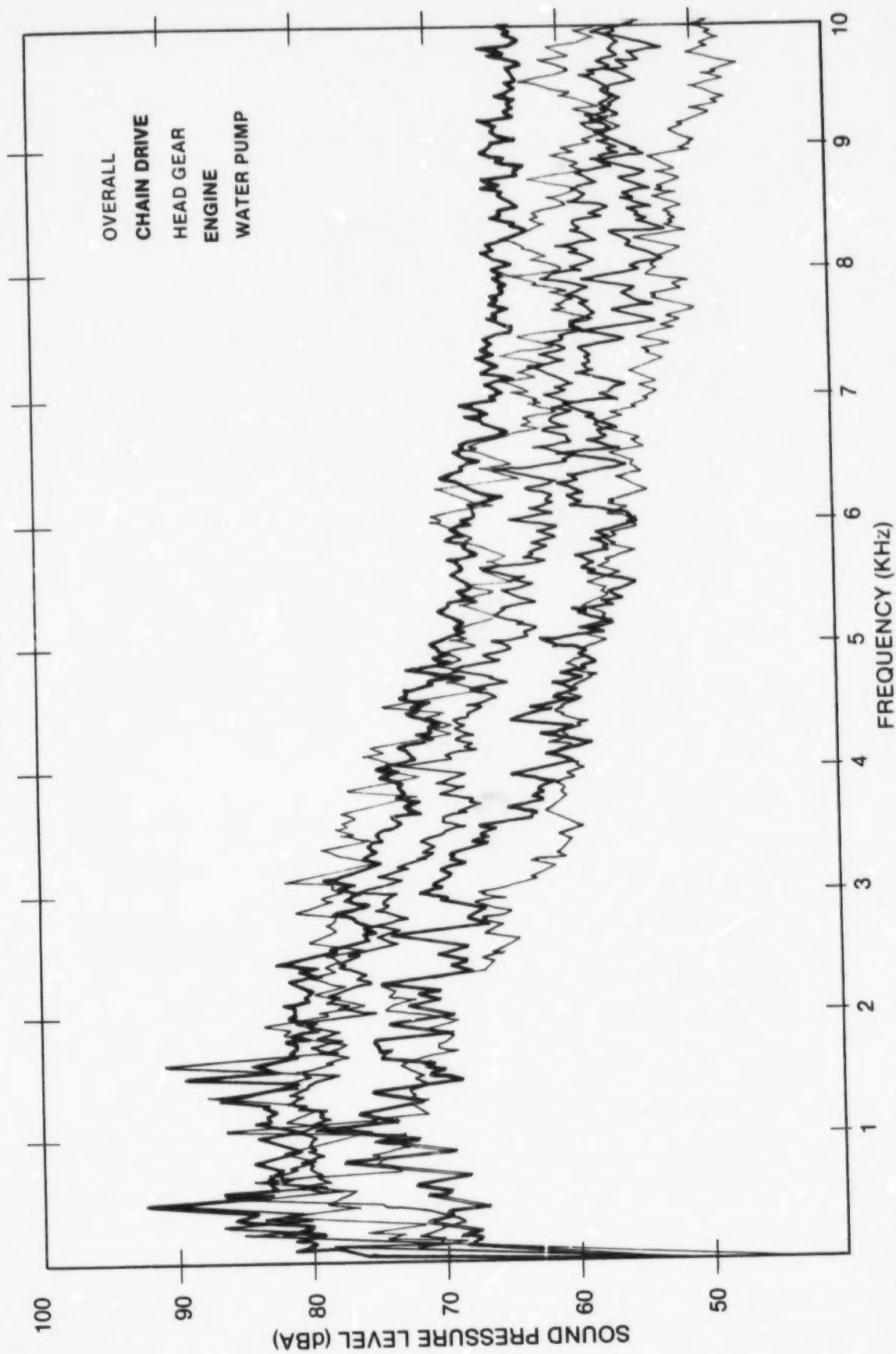


Figure 6.3

represents a significant risk in terms of hearing damage potential.

The relative importance of each noise component is illustrated by the overall height of each curve in Figure 6.3, but is more readily discerned by examining the corresponding overall dBA levels* for each, as summarized in Table 6.1. It should be noted that the test engine was equipped with an exhaust muffler, so exhaust noise was not a major component in this study. The dBA values shown in Table 6.1 are the same as those used in provincial noise regulations. It is obvious, therefore, that the eight hour exposure levels of 85 or 90 dBA currently allowed by provincial noise regulations are exceeded by each noise component.

TABLE 6.1

DEUTZ DIESEL DRILL NOISE SOURCES IN ORDER OF PRIORITY

(Ref Operator Position)

SOURCE	dBA	% SOUND ENERGY
(I) ENGINE	98	33.3
(II) HEAD GEAR (+ DRILL IMPACT)	97	26.4
(III) WATER PUMP	96.5	23.6
(IV) CHAIN DRIVE	95	16.7
TOTAL	103	100.0

* i e the sum of energy under each curve

Perhaps less obvious is the logarithmic characteristic of noise. That is to say, if one were to completely eliminate one of the major noise components, it may not be clear what net effect this would have on reducing the overall noise level. To illustrate this, the values in Table 6.2 were calculated. It is seen that elimination of engine noise only would reduce levels from 103 to 101 dBA, etc. This underscores the fact that all major noise components have to be treated before compliance with noise regulations can be achieved.

TABLE 6.2
EFFECT OF ELIMINATING NOISE COMPONENTS

COMPONENTS ELIMINATED	RESIDUAL dBA
NONE	103
ENGINE	101
ENGINE & HEAD GEAR	99
ENGINE & HEAD GEAR & WATER PUMP	95
ENGINE & HEAD GEAR & WATER PUMP & CHAIN DRIVE	90

A more sophisticated analysis technique was tested by the National Research Council on the same drill one week prior to the measurements described above as a check on the technique in the event that it might prove useful in the future. Virtually identical results were obtained, so they will not be discussed in this report.

6.3 Hatz Diesel Measurements

Measurements on the Hatz diesel were carried out at the same location as the Deutz, but the drill was not in operation at the time. Furthermore, the measurement team was visiting the site in preparation for the Deutz study, so was not equipped to conduct a set of measurements like those previously described. It was possible, however, to operate the Hatz diesel by itself and with the head gear turning but no drilling taking place. Overall noise levels (dBA) were measured using a Bruel & Kjaer type 2205 sound level meter equipped with a 1/2 inch condenser microphone. Tape recordings of major noise components were made on a Nagra SN tape recorder and subsequently analyzed on the Nicolet spectrum analyzer previously described.

Key results are shown in Figure 6.4. As with Figure 6.3, the vertical scale represents A-weighted sound pressure level and the horizontal scale is frequency, but in this instance over the range 0 to 2000 Hz. Since there was no means of isolating each noise source individually, measurements for the narrow band analyses were made within 2 inches of each source. For this reason, absolute noise levels observed are higher than what would normally be heard approximately three feet away. However, amplitude and frequency information are meaningful relative to each other, because the microphone position from each source was held constant. It is seen that with the Hatz diesel in place, the head gear (plus chain drive and gear tower assembly) becomes the dominant noise source. The dBA values noted in parentheses are overall noise levels measured three feet away from each source, except for the transmission value. The latter number (80 dBA) is an approximation based on an estimate of the decrease in sound pressure level which would result by moving the microphone three feet away from the source.

NOISE SPECTRA OF DIAMOND DRILL EQUIPPED
WITH HATZ DIESEL

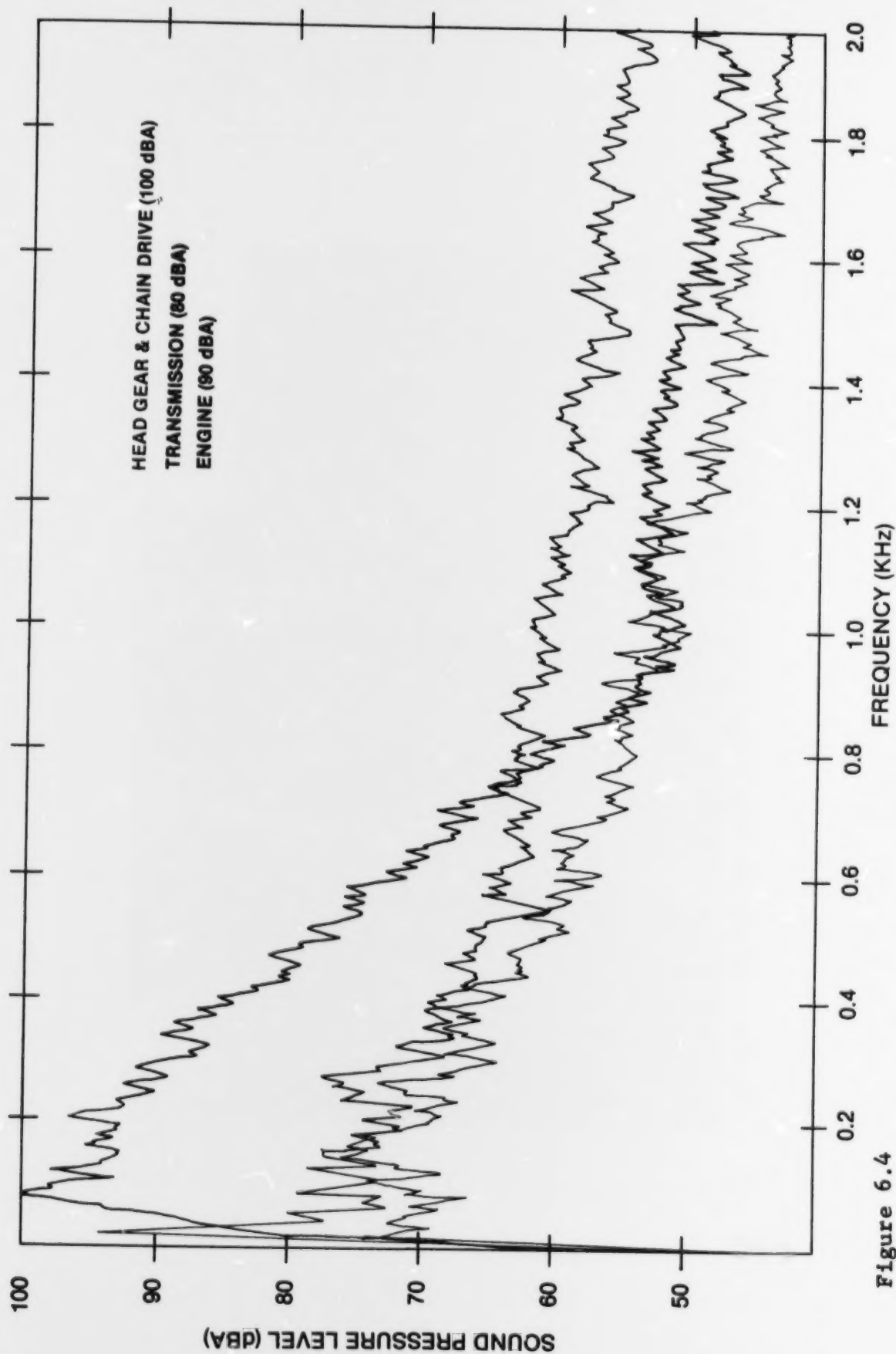


Figure 6.4

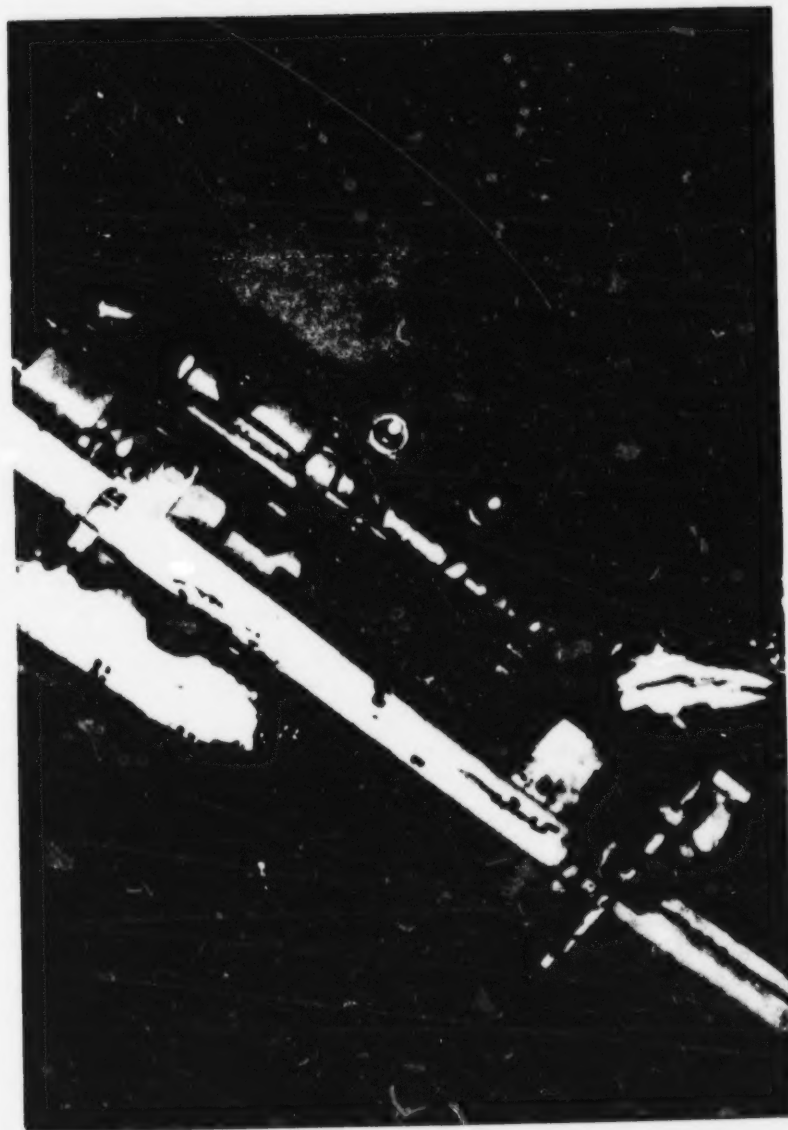


Figure 6.5 The temporary bulkhead positioned behind the drill head to isolate the sounds of the engine and transmission.

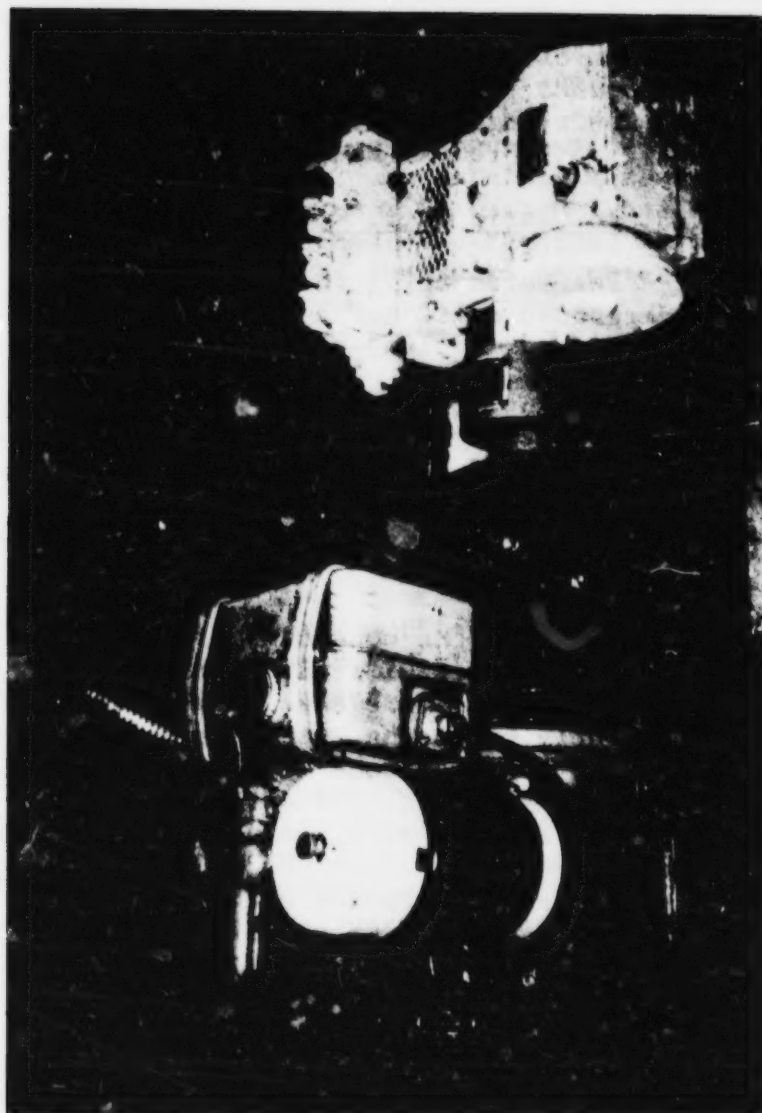


Figure 6.6 The water pump used for the test was powered by a Hatz diesel engine.

Comparing the Hatz and Deutz data, it is evident that the Hatz engine operates at a noise level 8 dBA lower than the Deutz (90 and 98 dBA respectively) in the test environment. The 100 dBA level measured near the head gear with the Hatz engine agrees very closely with the sum of the head gear and chain drive components (99 dBA) measured separately during the Deutz engine study. The water pump noise level would remain the same in either case.

6.3 Pneumatic Drill Measurements

Pneumatic drill tests were conducted in an underground drift having a "Y" configuration when viewed in plan, with approximate cross-section dimensions of 10' x 10' x 7'. The drill was located at the junction of the "Y", with the water pump located approximately 8 to 9 feet away along one branch of the "Y", and the drill exhaust hose strung out approximately 25 feet along the other branch, in the direction away from the drill.

Prior to the conducting of these measurements, State Industries Limited of Winnipeg expressed interest in having evaluated a muffler which apparently was being tested on pneumatic diamond drills by the Manitoba Division of Inco Metals Company. Arrangements were made to test their Model 5A and 2-3 mufflers and it was decided to include tests on a Cowl Model TS25SR spiral muffler for comparison purposes. The latter unit had been previously used on the Deutz diesel and was used in this study because it was available.

Measurements were conducted with the GenRad precision sound level meter described previously. Tape recordings for subsequent spectrum analysis were planned, but instrumentation problems experienced on-site prevented recordings from being made.

Results of this study are summarized in Table 6.3. It should be noted that numerous inconsistencies were noted upon examination of the original data. These are believed due to fluctuations in drill air-supply pressure during testing and undersizing of the mufflers used in the tests. The data for the drill in Table 6.3 is for levels measured in the operator's position unless otherwise indicated, and was selected as the best indicator of the patterns which appeared to be emerging. Water pump data was measured three feet from the pump with the pump operating by itself. All data should be regarded as preliminary results rather than data on which firm conclusions can be drawn.

Both the State and Cowl mufflers reduced exhaust noise from the water pump, with the Cowl muffler achieving the greatest reduction. The State muffler was left on the water pump to avoid interference effects with subsequent measurements to be conducted on the drill.

Two sets of measurements were then conducted with the Cowl and State mufflers consecutively installed directly on the drill's air motor exhaust and two different sets of results were obtained.

Variations may have been the result of line pressure fluctuations, restrictions in air flow due to undersized mufflers, freezing inside the mufflers, etc. However, no major changes in test conditions were apparent. Therefore, it is difficult to conclude whether any real improvement in noise level was observed when using either muffler or the original hose on the motor exhaust.

When measurements were made along the exhaust hose (3' from drill, 6' from drill, etc), it was interesting to note that noise levels dropped off to 94 dBA. This suggests that the noise levels being measured near the drill while the hose or a muffler is in place are the result of something

TABLE 6.3
SUMMARY OF PNEUMATIC DIAMOND DRILL MEASUREMENTS

NOISE SOURCE	TEST CONDITION	NOISE LEVEL (S) IN dBA
WATER PUMP (BB4-7M 4" VANE TYPE 11 HP)	NO MUFFLER	102
	STATE MUFFLER (#2-3)	97
	COWL MUFFLER	91
	NO EXHAUST HOSE OR MUFFLER	109.5 111*
	NORMAL EXHAUST HOSE	108.5
	COWL MUFFLER ON DRILL	103 109*
	STATE MUFFLER (#5A) ON DRILL	105 105*
	EXHAUST HOSE ONLY (@3' 6' 12' 25')	108.5 105 99 94
	EXHAUST HOSE + COWL MUFFLER ON END	110 105 98.5 94.5
	EXHAUST HOSE + STATE MUFFLER ON END	105.5 104 102 107
DRILL (BBS JV 2 CYLINDER "V" TYPE 27 HP)	LAGGED EXHAUST HOSE + COWL MUFFLER	106.5 101.5 99 93.5
	LAGGED EXHAUST HOSE + STATE MUFFLER	108.5 104.5 103.5 101

* duplicate tests

other than the air motor exhaust. In fact, the subjective feeling of those doing the measurements was that the bevel gears were the dominant noise source under these operating conditions. Installing a Cowl muffler at the end of the exhaust hose and lagging the exhaust hose with fibreglass had virtually no effect on further reducing exhaust noise levels. Similar tests with the State muffler increased noise levels at and near the end of the exhaust hose, suggesting the muffler was restricting air flow and thereby increasing air turbulence and hence noise at that point.

Due to the anomalies which were observed in this data, additional tests will be required before valid conclusions can be drawn. In that event, line pressures should be controlled and mufflers, etc used in tests should be sized carefully to avoid flow or other unsuspected problems. Meanwhile, available data does suggest that initial noise control efforts for pneumatic drills should be directed at the bevel gears rather than at the air motor exhaust.* This is encouraging in that work done to reduce bevel gear noise for surface rigs should be adaptable to underground rigs.

* assumes exhaust hose is in use on drill. Muffling of water pump air motor exhaust could be beneficial as illustrated by Table 6.3

SECTION 7

DIAMOND DRILL ENGINE ENCLOSURE



7.0 DIAMOND DRILL ENGINE ENCLOSURE

7.1 Objective

The objective of this portion of the project was to design an engine enclosure which would reduce the sound level of the engine used on a diamond drilling rig to 80 dBA at the operator's station. The design principles developed can be applied to any engine, but the engine used in the drawings was a General Motors Model 3-53 diesel engine. This engine is a three cylinder, blower aspirated, two stroke cycle, water cooled power unit.

The enclosure for the engine must meet several other conditions in addition to a reduction in sound level. These are:

- a) Performance of the engine must not be reduced to any significant degree.
- b) The operation of the engine cannot be hampered.
- c) The sound enclosure must not create a fire risk.
- d) All maintenance points must be easily accessible.
- e) The enclosure must disassemble without great difficulty to allow for engine changeout.
- f) The enclosure must be durable enough to withstand the abuse received in a drilling camp.

7.2 Noise Attenuation

The overall noise level of the engine is the result of the logarithmic addition of all the individual noise sources. These sources include the combustion process, the fan, intake blower, exhaust, valve train, injectors, pumps, etc. To attempt to individually isolate all the noise sources is impractical and an overall enclosure was designed. Engine manufacturers are in the process of redesigning individual machine components to reduce noise levels at the point of generation. This program will take many years to complete, however, and will do little to quiet the engines which are already in use.

Ideally, an overall engine enclosure would not contain any openings and a simple sound barrier of sufficient density would be adequate. However, reality dictates that several openings must be provided for the following reasons:

- a) to introduce fresh cooling air
- b) to discharge hot cooling air
- c) to discharge engine exhaust gases
- d) to pass wiring and control cables, hoses and drive shafts
- e) for service access.

7.2.1 Nature of Sound

Sound readings used in the design of this enclosure were taken from a diamond drill equipped with a Deutz diesel. Actual sound readings for a General Motors diesel were not available. However, it was assumed that the Deutz diesel would likely be noisier due to the fact that the engine was cooled with air and not with water.

Sound levels were as shown in Table 7.1.

TABLE 7.1

OCTAVE BAND CENTRE	LEVEL dBA
63	70
125	78
250	87
500	94
1K	83
2K	93
4K	78
8K	70
TOTAL COMBINED SOUND LEVEL = 98 dBA	

To reduce the sound levels, the engine enclosure has been designed as follows.

7.3 Enclosure Design

7.3.1 Enclosure Wall Configuration

The walls of the enclosure are constructed from 22 gauge sheet metal lined with a 1 inch thick sheet of fibreglass acoustical insulation. To prevent the fibreglass from becoming saturated with oil or dust, a 1 mil sheet of Dupont kapton plastic film will be used to encase the fibreglass. Kapton film was chosen for this application because of its high temperature resistance and physical strength. The film is suitable for constant service at 220 degrees Centigrade (428 degrees Fahrenheit) and will not burn. The film will be wrapped over the fibreglass and the assembly will be glued to the wall. A protective sheet of perforated metal will be placed over the insulation to prevent accidental puncturing of the film.

The bottom of the engine enclosure is fabricated from 11 gauge mild steel and is not lined with fibreglass insulation. The bottom of the enclosure will be continually wetted with oil, diesel fuel and water. Lining this area would create a fire hazard and impede the flow of liquids to the drain. Heating devices such as gas torches are often used to warm engine oil pans for starting in severe weather. Direct contact of the flame from the torch on any film covered insulation in the bottom of the enclosure would destroy the film. The absence of insulation on the bottom and the heavy gauge thickness of the plate will prevent this area from being damaged in the field.

7.3.2 Cooling Air Inlet

To provide cold air for the radiator, provision must be made for drawing air into the

enclosure without letting the noise out. Noise at the inlet consists of the logarithmic addition of the engine noise to the fan noise. The present inlet design has a minimal resistance to air flow with effective sound attenuation. The sound leaving the enclosure inlet has direct and reflective transmission properties. The direct transmission properties are eliminated by the physical configuration of the inlet; that is, the sound source does not have a direct line of sight to the inlet opening and the reflective properties are absorbed by the 1-1/2 inch thick fibreglass lining. The fibreglass lining is plastic covered and protected with perforated metal as described in Section 7.3.1. A thicker lining is required in the inlet area to increase the absorption of the lower frequency sound waves.

Noise level from the inlet will be 80 dBA.

7.3.3 Cooling Air Outlet

To provide cooling air for the engine, provision must be made for discharging the air from the engine enclosure without letting too much sound out. The design parameters for the outlet are similar to the parameters mentioned in the cooling air inlet. The outlet is arranged so that direct transmission of the sound is not possible and reflective transmission is impeded. The only difference between the two conditions is that fan noise is not a consideration in the outlet design. Noise levels from this source will also be approximately 80 dBA.

7.3.4 Exhaust Noise

To suppress the noise from the engine exhaust system, a Cowl muffler is mounted in the exhaust system. The Cowl muffler has high sound attenuation properties with minimal exhaust restriction and should bring the noise levels from this source to

well below 80 dBA. The muffler is located within the enclosure and isolated from the walls of the enclosure with a short piece of flexible exhaust piping. A pipe thread is provided where the flexible pipe is connected to the enclosure so additional piping can be added to discharge the exhaust outside the drill shack.

7.3.5 Air Breather Noise

An air inlet silencer must be installed on all two stroke diesel engines with inlet blowers. The General Motors engine used as a model for this design was so equipped. To ensure that the engine always receives cool air from outside the enclosure, it is necessary to seal the air inlet filter from the remainder of the engine. The sound level produced with the filtered inlet can be further reduced by locating the inlet box in a recessed enclosure as shown on the drawings. The position of the air inlet port with respect to the face of the air inlet filter ensures that very little of the directly radiated sound will escape the enclosure. Reflected sound levels will also be reduced by the 1-1/2 inch thick insulation used on the air filter enclosure walls. A sound reduction of approximately 10 dBA can be expected from the inlet configuration.

7.3.6 Transmission Noise

A considerable amount of noise is released from the engine transmission. To reduce noise levels from this source, the transmission has been totally enclosed in a manner similar to the rest of the engine. To allow protrusion of the gear shift lever and the drive shaft, flexible bellows made of high density sound attenuating rubber have been installed. The rubber bellows will allow free movement of the components without a significant increase in sound levels.

The clutch shaft from the transmission has been fitted with a flexible coupling and the shaft has been extended through the enclosure wall. A ball joint is mounted where the shaft passes through the enclosure to permit free movement of the engine on its rubber mounts.

Ample space has been provided around the transmission to allow the engine cooling air to also cool the transmission.

7.4 Engine Cooling System

The addition of the engine enclosure severely impedes the flow of air around the engine and through the radiator. To meet the original design criteria it is necessary to maintain a sufficient flow of air to the engine without a loss in horsepower output. The original propeller fan supplied with the motor is cheap, compact and light, but it is not very efficient and will not move large volumes of air if there is too much resistance to air flow.

7.4.1 Impeller Design

The fan configuration required for this application must move slightly more air at greater resistance than the original fan but cannot require a greater amount of horsepower from the engine. To meet this criteria, a more efficient, backward inclined fan with an airfoil blade was selected. This fan meets the above requirements and has the added advantages of turning at about the same speed as the original unit but with a lower noise level. The fan requires approximately the same amount of room as the propeller unit and must be installed with an air inlet cone to obtain the necessary performance criteria.

7.4.2 Radiator Design

The present radiator used on the engine will supply adequate cooling in the new enclosure

with the new radial fan. Additional gains in sound control, cooling efficiency and space utilization could be achieved if a donut shaped radial radiator was installed. Inquiries for a radial radiator were made, but with little success. The tooling required for a radiator of this configuration does not appear to exist on this continent. A proposal was made by one supplier to fabricate a square radiator with radial air flow characteristics, but the price of \$2000 a unit was not feasible. Engine vibrations often break the existing radiators and it was felt that the design should utilize a unit which was readily available.

7.5 Engine Maintenance Accessibility

For a successful enclosure design, it is essential that all the engine maintenance functions be performed without interference from the engine enclosure. Doors and removable covers have been located on the enclosure so that this criteria is met. All doors are sturdily constructed and must seal effectively when closed. Neoprene foam is used for gasketing on all openings.

7.5.1 Hinged Side Doors

Large hinged doors are installed on both sides of the enclosure to provide access to the most commonly serviced engine components. Through these doors, access can be made to the oil and fuel filters, the oil drain plug, the fan belt, the inlet and exhaust manifold, the water pump, the oil cooler, the alternator and the oil breather tube. These doors are equipped with slip-joint hinges and can be easily removed if necessary.

7.5.2 Top Access Hatch

The top of the engine enclosure unlatches and flips back to provide access to the engine valve covers, fuel injectors, radiator, muffler and air breather. The top access consists of

two hatches; one directly over the engine and another over the radiator. Both doors can be opened independently. The cooling air exhaust plenum is an integral part of the engine cover hatch and is therefore moved out of the way when the hatch is opened.

The overhanging front of the hatches is also hinged to provide easy access to the air breather without raising the entire top of the enclosure.

7.5.3 Back Covers

Covers at the back of the engine enclosure, directly above the transmission, provide access to the hydraulic pumps and the oil dip stick. These covers are equipped with slip-joint hinges and are of the same construction as the other doors.

Hoses from the hydraulic pumps are piped to a common bulkhead on the engine enclosure. When operators are setting the drill up in the field, it will not be necessary to enter the enclosure to hook up the hydraulic lines. All connections will be made outside the enclosure.

7.5.4 Transmission Cover

A small hinged door is provided on the top of the transmission cover to inspect the transmission oil level and to add fluid. The fill and drain ports on the transmission will be piped to facilitate use of a dip stick.

7.5.5 Fluid Drains

To safely drain fluids from the engine, it is necessary to pipe all major drainage points out of the enclosure. The bottom of the enclosure acts as a large drainage pan to collect miscellaneous oil leaks and direct them to a central enclosure drain.

Fuel oil is drained from the fuel oil filters before engine start-up. The discharge valves on the bottom of the filters are to be piped to a location directly above the enclosure drain hole.

Crankcase oil is normally drained directly from the oil pan. To prevent this oil from splashing over the bottom of the enclosure, a second pan will be installed directly under the crankcase drain. This pan will collect the oil and direct it to the main enclosure drain.

The radiator drain will be piped to a point below the engine and not to the main enclosure drain. This arrangement will allow draining of the radiator coolant without fear of contamination from the engine oil and fuel oil residue in the main enclosure drain.

7.6 Enclosure Disassembly

The enclosure is constructed of separate panels consisting of left and right side panels, top panel, forward frame, rear frame, cooling air inlet enclosure, top and side transmission cover and the enclosure bottom panel. The bottom panel forms the main frame of the enclosure and the majority of panels are fastened to it. All panels are bolted together and sealed with gasketed seams. All hoses, electrical wires and control cables are routed through the rear frame. Where possible, the wires and cables are equipped with fittings for ease of engine removal. With a tripod or pitman, the engine can be withdrawn and replaced by removing only the side panels, transmission cover and top cover. The radiator and fan would stay within the enclosure.

The enclosure assembly is mounted on skids to permit winching of the unit in and out of the drill shack.

7.7 Drill Shack Modifications

The radial fan and cooling ducts make the sound reduced engine longer than a standard engine. The enclosure is 2 feet 6 inches longer and 1 foot 6 inches higher. The end of the drill shack must be extended and the roof will have to be raised to a minimum height of 9 feet 0 inches. The increased height is needed to open the access doors.

Additional modifications will also be required on the main drilling frame. The enclosure is taller and wider than the conventional engine and a special frame will have to be designed to support the unit.

SECTION 8
DRIVE NOISE



8.0 DRIVE NOISE

While an evaluation of gear components was not a specific requirement of Phase II some exploratory work was undertaken in order to be able to make recommendations for future work.

In general, the gears and other drive components in use on diamond drills were designed a number of years ago and replacements are based on the old design. There are a number of instances of gear failure on the drills indicating either weakness in design or misalignment. Both of these are not conducive to quiet operation.

The gear train in use consists of spur gears and a bevel gear. A change box is often incorporated into the spur gear design. The bevel gear is used as the means of disconnecting the drive when the head is swung away to permit rod pulling. The hinge and catch system does not permit precise alignment over the life of the machine.

There are a number of instances of quiet gears on the market such as the use of helical rather than spur gears and spiral bevel or hypoid instead of bevel gears.

Drive noise levels increase with power and with pitch line velocity. The noise is very complex due to the fact that it is the result of an interaction between tooth meshing errors, which cause oscillations which in turn create shaft deflections, bearing loads and housing oscillations. If the housing oscillations result in a resonant condition, the noise may actually be magnified.

Table 8.1 provides a list of design methods that can be used to reduce drive line noise. Some of these, such as the use of helical gears are reliable and have been used for years. Others, such as the use of phasing, are not as reliable and must be attempted cautiously.

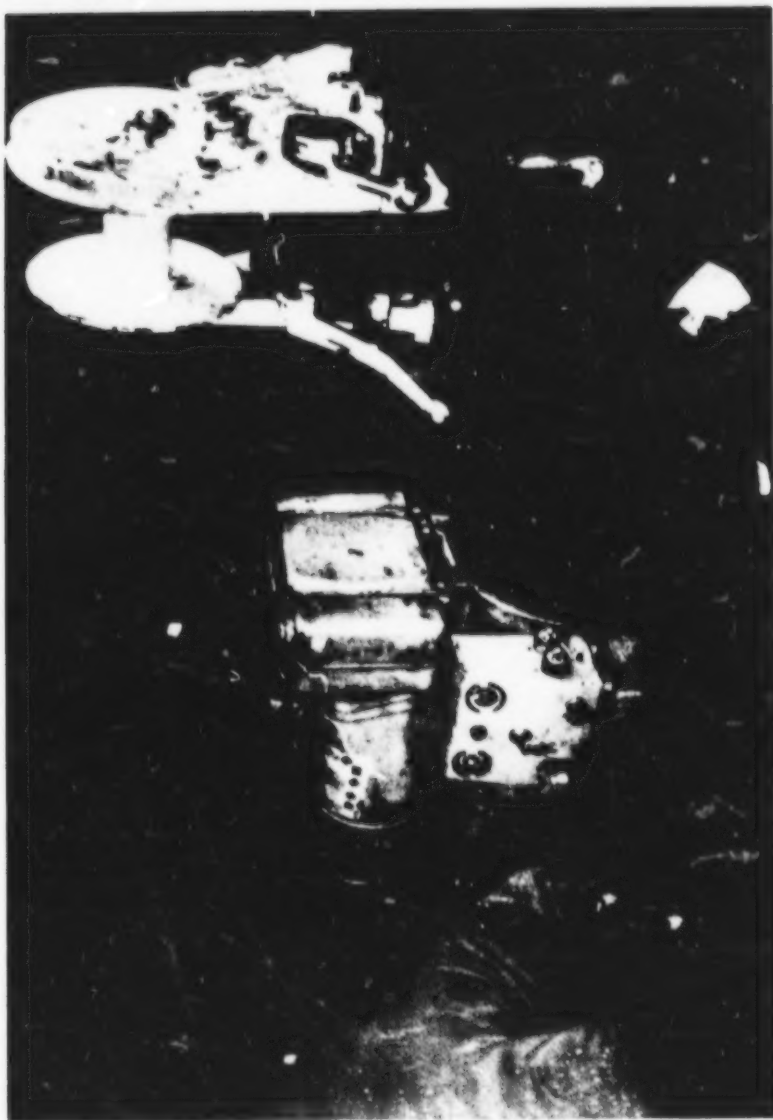


Figure 8.1 A view of the hoist drill transmission and automotive transmission. It would be difficult to provide an enclosure for the drill transmission.

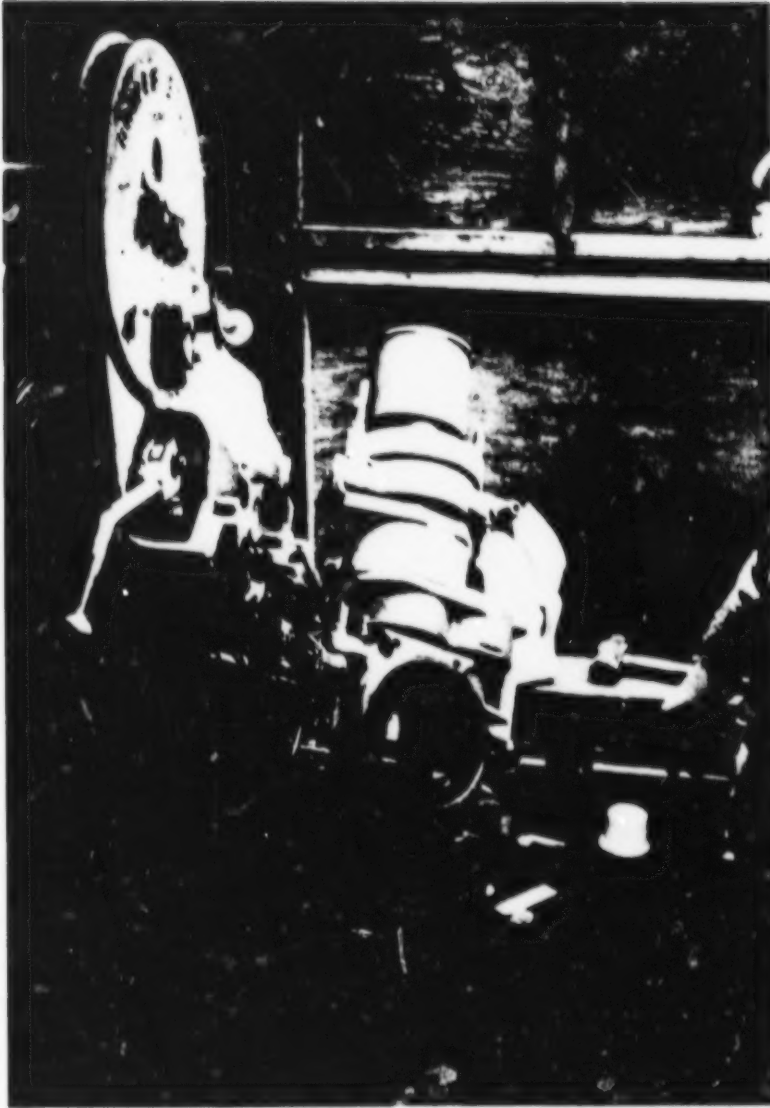


Figure 8.2 The head swings away from the drill to allow room to pull the rods. The bevel gear produces a great deal of the noise.



Figure 8.3 A close-up of a spur gear showing spline and tooth detail.
Note the tooth damage.

ERRATUM

Due to a printer's error, the pictures on Pages 66 & 67 are transposed.



Figure 8.4 A close-up of a bevel gear showing tooth damage.

It should also be noted that housing resonance, if it occurs, will completely negate any gains made by other means. This over-riding factor requires very careful design if it is to be avoided.

When some experts were contacted with regards to reducing the noise level, most agreed that some of the available methods would work on the drill transmissions. They also indicated that, without doing some experimenting, there was no way to put actual figures on the amount of gain available.

For this reason it will be necessary to undertake a gradual improvement, first using the existing housing and trying better gears and then, if necessary, designing a complete new gear box. It may also be possible to incorporate noise enclosures but this will be made difficult by the need for accessibility and cooling.

TABLE 8.1

DRIVE NOISE REDUCTION METHODS

METHOD	RESULT
USE HELICAL CUT	MORE UNIFORM MESHING
IMPROVE KINEMATIC ACCURACY	MORE UNIFORM MESHING
INCREASE CONTACT RATIO	REDUCE DYNAMIC LOAD
USE NON-METALLIC GEAR MATERIAL	REDUCE NOISE TRANSMISSION
REDUCE PITCH LINE VELOCITY	REDUCE DYNAMIC LOADS
STIFFEN SHAFTING	IMPROVE TOOTH ALIGNMENT INCREASE LIFE
CONTROL BACKLASH	REDUCE NOISE DURING LOW LOAD
GEAR MESH PHASING	REDUCE NOISE BY CANCELLATION
REDUCE HOUSING DYNAMIC RESPONSE	DEADEN NOISE TRANSMISSION
BLANKET, BARRIER OR ENCLOSURE	CONTAIN NOISE
PROVIDE VIBRATION ISOLATION BETWEEN GEAR AND SHAFT	REDUCE STRUCTURE-BORN NOISE



SECTION 9

NOTES ON REGULATIONS



9.0 NOTES ON REGULATIONS

Diamond drillers will normally be bound by Provincial Regulations laid down by respective Departments of Labour or Workmen's Compensation Boards. Exceptions would include drilling carried out underground or on the property of an operating mine, which would come under the jurisdiction of the local mining act, or drilling carried out for the Federal Government, which would come under the Federal Regulations. Noise regulations are usually the same between regulating bodies within a given province, but do vary between provinces, as indicated by the attached summary (Table 9.1). Regulations are constantly under review, so it is always advisable to check for possible revisions before undertaking any major work which could be affected by the prevailing laws. However, a few trends have become apparent over the past few years and are discussed below.

The first obvious trend, which can be seen in Table 9.1, is that all the provinces are lowering the allowable eight hour limit of continuous noise exposure to 85 dBA. Impulse noise will not usually be a concern for diamond drillers. As of June 12, 1980, half the provinces had adopted this limit and the others remained at 90 dBA. Whether the permitted noise level is likely to be regulated below 85 dBA in the future cannot be determined with certainty. However, it is not probable, since Canadian regulations generally follow the lead of the United States and the United States, after six years of debate,* have recently decided to hold their permissible level at 85 dBA.

Although noise regulations have been in effect in most provinces since the early to mid 1970's, enforcement of the regulations has been lax to date. This laxity is in the process of changing as evidenced by the passing of Bill 17 in Quebec, Bill 70 in Ontario,

* The Bureau of National Affairs Inc
Noise Regulation Reporter, January 14, 1981

TABLE 9.1 CURRENT OCCUPATIONAL NOISE REGULATIONS OF WIDE APPLICATION IN CANADIAN PROVINCES (JUNE 12, 1980)

JURISDICTION	STEADY-STATE NOISE			IMPULSE NOISE	
	MAXIMUM PERMISSIBLE DAILY 8 HOUR TWA EXPOSURE LEVEL (dBA)	TIME/INTENSITY DOUBLING RATE dBA	MAXIMUM PERMISSIBLE LEVEL WITHOUT HEARING PROTECTION (dBA)	MAXIMUM PERMISSIBLE LEVEL (dB PEAK SPL) PERMISSIBLE NUMBER OF IMPULSES PER DAY	RATE OF INCREASE (6)
TREASURY BOARD	90	5	115	140 (3)*	(7)*
ALBERTA	85	5	115	140 (3)*	(7)*
BR COLUMBIA	90	3	105	140/90	10
MANITOBA (1)	85	5	115	140/100	10
N BRUNSWICK	90	5	115	140/100 (4)*	10
NEWFOUNDLAND	85	5	115	140/100	10
NOVA SCOTIA	85	5	115	140/100	10
ONTARIO	90	5	115	(5)*	
QUEBEC	90	5	115	140/100	10
SASKATCHEWAN (8)*			85	(5)*	
P E I (2)*					

()* Refer to TABLE 9.1 NOTES

TABLE 9.1

NOTES

1. No permissible noise levels are specified in the legislation but are to be determined by the responsible branch or division within the Department of Labour. Currently, the threshold limit values (TLV) of the American Conference of Governmental and Industrial Hygienists (ACGIH) are adopted for this purpose.
2. No other provision than that "noise levels in places of employment shall be kept within a range which is comfortable and harmless to employees".
3. No provision on the permissible number of impulses of 140 dB peak SPL.
4. The level of impulse noise is given in dBA, obviously by mistake.
5. No provision on impulse noises.
6. Rate of increase of number of impulses for each 10 dB increase in the peak SPL of the impulse.
7. No provision on the interrelation between the permissible number and the peak SPL of the impulse.
8. Permissible noise levels are not specified in the legislation, but are to be determined by the responsible branch within the Department of Labour. TWA concept is not adopted for steady-state noise.

and the hiring of inspectors by the Workers' Compensation Board in British Columbia. It is fairly certain that these provinces will soon adopt the current U S Occupational Health and Safety Administration practice of citing industry for violations of noise regulations and fining those unwilling to undertake the necessary corrective action. Other provinces will probably follow suit in time.

Wise industries have taken advantage of the grace period to develop noise control methods for noisy equipment with no "off the shelf" solutions. This avoids a potential problem of having to spend money on inappropriate noise control equipment in order to comply with government citation deadlines, and then having to go back and spend more money searching for the correct solution.

Industries who have been slow getting started can still avoid this type of confrontation with authorities provided that they can prove they have a program underway which will deal with existing noise problems. At the moment at least, a sincere intent to comply with the spirit of the law will usually avoid the imposition of a deadline for resolving noise problems which require some development work. However, compliance deadlines may be imposed where proven noise control methods are known to exist.

In summary, both noise regulations and the methods in which they are applied across Canada are in a state of flux. However, it is certain that currently noisy operating equipment will be silenced in the future - by force, if not by choice. Original equipment manufacturers in Europe and the United States who were forced to live with noise regulations ten years ago, already have a head start on producing quieter-operating equipment lines. These products will have an increasingly larger impact in the Canadian marketplace if Canadian manufacturers do not start developing competitive products.

APPENDICES



APPENDIX I

STATEMENT OF WORK:

1. It has been established that the overall noise level of diamond drilling equipment is the composite of several individual major sources. It has also been established that even by totally eliminating one of these (say the power source), the residual noise level will still exceed the legal limit set by provincial authorities. Moreover it is now known that the contribution of major noise sources must be determined in the field under actual operating conditions, and not merely under laboratory conditions.

Rather than concentrating on reducing the noise level of any one known source at this point, the contractor shall undertake a series of tests to determine the individual noise levels contributed by all major sources (such as gear trains, drilling head, accessories, prime movers, etc.) under both shop and actual operating conditions.

All major groups of diamond drilling equipment currently used in Canada, including diesel and pneumatic power sources, mechanical and hydraulic drill designs, at both above - and underground locations, shall be examined.

2. After establishing the individual contributions of the standard diamond drill components, the contractor shall examine the best steps (both on theoretical and practical grounds) that may be taken, to dampen these noise levels. Any work done by others in this field should also be examined and evaluated.
3. Wherever special noise reducing modifications have already been developed the contractor shall study their adaptability to diamond drilling requirements and, wherever possible, undertake the necessary modifications.

"The Silent Power System" developed by Hatz diesels, the special muffler developed by INCO at Thompson, Manitoba, and the muffled drill design of Canadian Longyear (with power source removed to large distances) should be given special attention.

4. The contractor shall undertake noise level measurements with as many of the specially developed noise suppression equipment (point 3) as can be adapted to diamond drilling.

These measurements shall be taken both under shop and actual operating conditions.

5. The contractor shall evaluate the results of the foregoing measurements (point 4). Wherever further improvements are feasible, these should be examined and executed.
6. The contractor shall submit a carefully reasoned proposal for recommended future work in area of interest, including both time and cost estimates.

The requested proposal should include a cost estimate and time schedule itemized along the lines detailed in the section on "Statement of Work".

APPENDIX II

State Industries Limited manufactures a polyurethane muffler for use on both stopers and diamond drills. The present device for diamond drills is sized for a CP-65.

State Industries Limited
1104 Wall Street
Winnipeg, Manitoba
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Budd (Canada) Incorporated manufacture a muffler sold under the trade name (Cowl).

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